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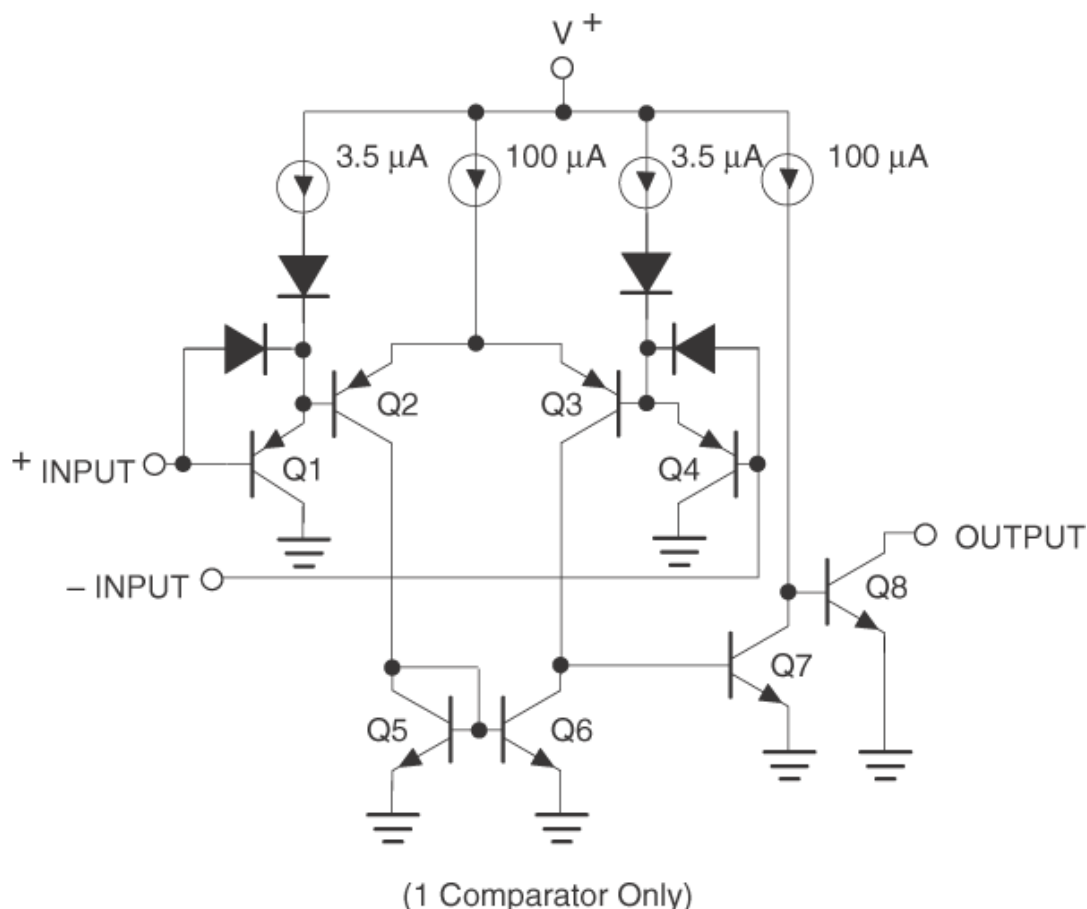
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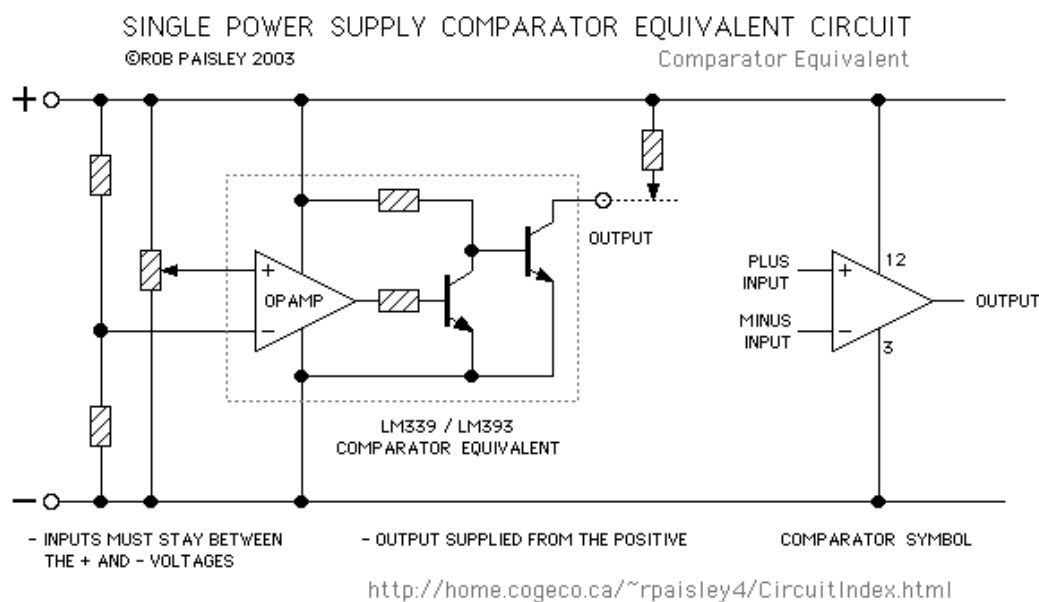
## Voltage Comparator Information And Circuits

This page provides basic information about voltage comparator integrated circuits and is to act as reference material for other circuits. The circuits shown are based on the LM339 Quad Voltage Comparator chip or the LM393 Dual Voltage Comparator chip. These devices are functionally identical. The LM311 Voltage Comparator can be used for these applications as well and also has a number of unique features.

### Internal Circuitry For 1/4 Of An LM339



## Comparator Equivalent



## Single Supply Comparator Equivalent schematic

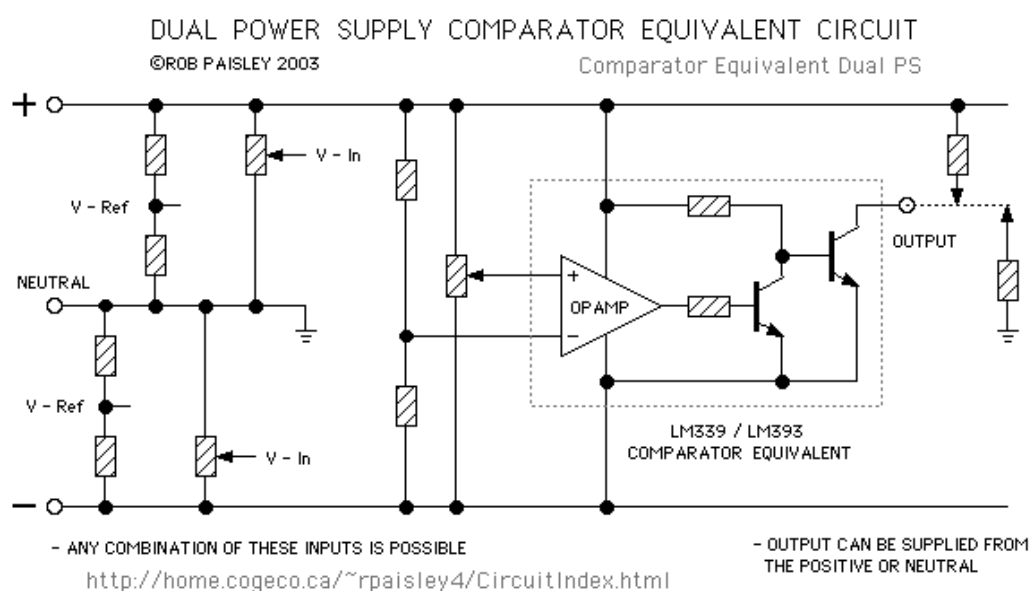
An integrated circuit "Voltage Comparator" is equivalent to an Operational Amplifier, Such as the LM358 or LM324, with two NPN transistors added to the output of each amplifier. (Refer

to the above schematic.) This arrangement produces an "Open Collector" output for each of the four comparators in an LM339 chip. Each output can sink 15 Milliamps and can withstand voltages of up to 50 Volts.

The output is switched ON or OFF depending on the relative voltages at the PLUS and MINUS inputs of the comparator, see the rules below. The inputs are quite sensitive and a difference of only a few millivolts between the two will cause the output to turn on or off.

The LM339, LM393 and LM311 comparator chips can operate from a single or dual power supply of up to 32 volts maximum.

When operated from Dual or Split power supplies the basic operation of comparator chips is unchanged except that for most devices the emitter of the output transistor is connected to the negative supply rail and not the circuit common. An exception to this is the LM311 which has a separate emitter terminal that can be connected to either.



## Dual Supply Comparator Equivalent schematic

When operated from Dual or Split power supplies the input voltages can be above or below the common or zero voltage of the supply. If needed, one of the inputs can be connected to the common so that a 'Zero Crossing' detector is created.

## Comparator Operation

The following drawing show the two simplest configurations for voltage comparators. The diagrams below the circuits give the output results in a graphical form.

For these circuits the REFERENCE voltage is fixed at one-half of the supply voltage while the INPUT voltage is variable from zero to the supply voltage.

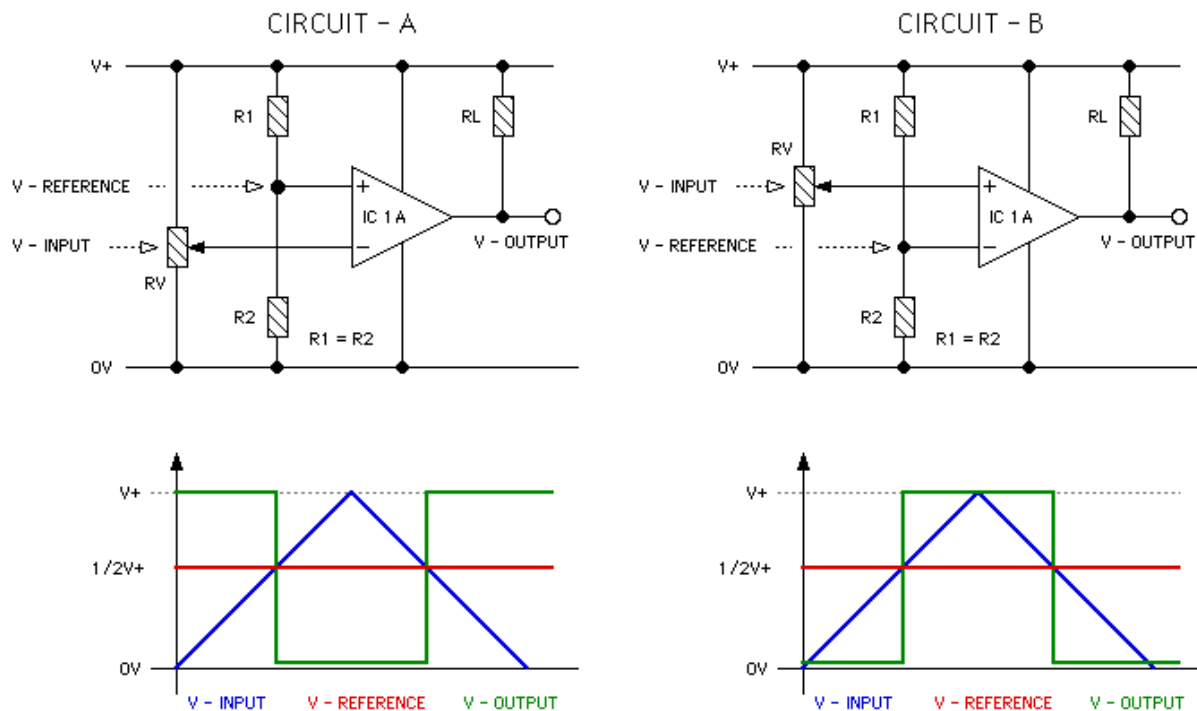
In theory the REFERENCE and INPUT voltages can be anywhere between zero and the

supply voltage but there are practical limitations on the actual range depending on the particular device used.

### BASIC OPERATION OF VOLTAGE COMPARATORS

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Comparator Operation



<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

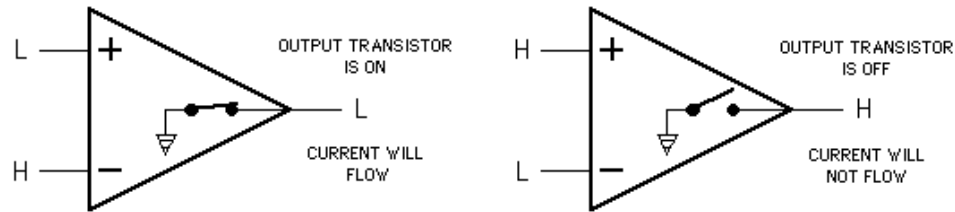
### Basic Comparator Operation

## Input Vs. Output Results

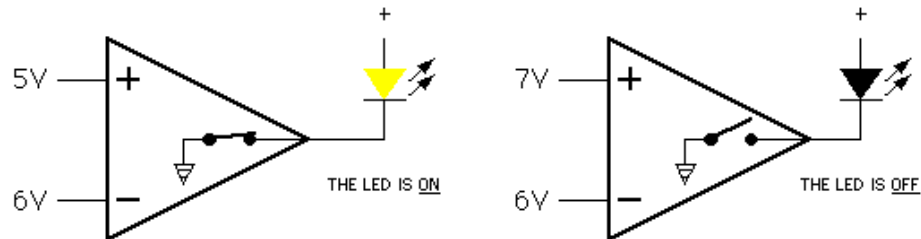
1. Current WILL flow through the open collector when the voltage at the PLUS input is lower than the voltage at the MINUS input.
2. Current WILL NOT flow through the open collector when the voltage at the PLUS input is higher than the voltage at the MINUS input.

### COMPARATOR - INPUT Vs. OUTPUT RULES

Comparator Rules Sheet 2a



### IN OTHER PICTOGRAMS



<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

### Input Vs. Output Results

## Input Offset Voltage

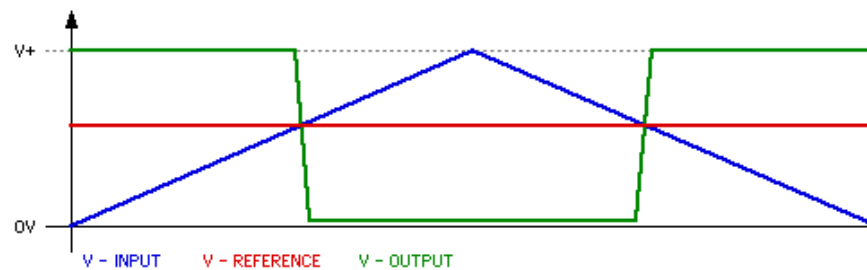
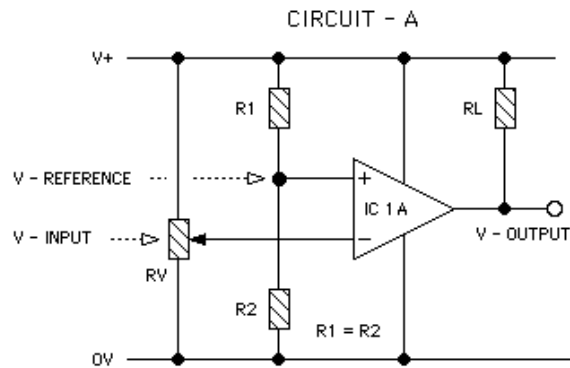
Voltage comparators are not perfect devices and in some instances may suffer from the effects of a parameter known as the Input Offset Voltage. This problem normally occurs when the Input voltage changes very slowly. The Input Offset Voltage for many comparators is only a few millivolts and in most circuits it can be ignored.

The net result of the Input Offset Voltage is that the output transistor does not fully turn on or off when the input voltage is close to the reference voltage.

The following diagram attempts to illustrate the effect of the input offset voltage with a slowly changing input voltage. This effect increases as the output transistor current increases so keeping the value of  $R_L$  high will help reduce the problem.

### EFFECT OF INPUT VOLTAGE OFFSET

©ROB PAISLEY 2002 Comparator Input Offset



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### Effect Of Input Offset Voltage

## Input Offset Voltage And Hysteresis

The effects of the input offset voltage can be countered by adding hysteresis to the circuit. This causes the reference voltage to change when the comparators output goes high or low.

The effect is that as the input voltage slowly changes the reference voltage will quickly change in the opposite direction. This gives the comparator a "snap" action. See the following paragraphs for more information.

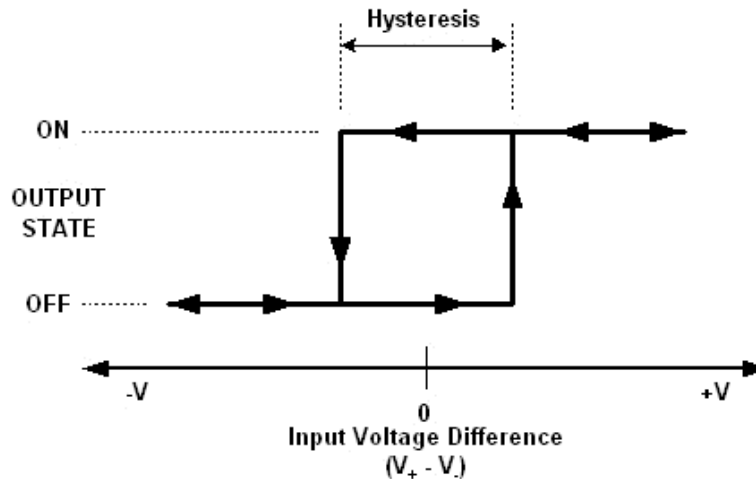
## An Explanation of Input Hysteresis Voltage

Hysteresis is the difference between the input signal levels at which a comparator turns off and turns on. A small amount of hysteresis can be useful in a comparator circuit because it reduces the circuit's sensitivity to noise, and helps reduce multiple transitions at the output when changing state.

Sometimes, in a discrete design, there is a need to add an external resistor between the comparator's output and the positive input, creating a weak positive feedback loop. When the output makes a transition, the positive feedback slightly changes the positive input so as to reinforce the output change.

A mechanical analog of this effect can be found in many electrical switches. As you move the handle just past the center point, a spring in the switch will try to pull the handle all the way

over, ensuring that the switch ends up in a definite ON or OFF state.



### Input Hysteresis

The diagram above shows a hysteresis 'loop' that describes how a comparator functions. The horizontal 'X' axis is the input, and represents the difference of the two input voltages. The vertical "Y" axis represents the comparator's output state.

If the comparator is initially 'OFF', the MINUS input voltage has to become slightly above the PLUS input voltage before the comparator output turns 'ON'. This is represented by moving right along the bottom part of the loop.

Once the comparator is 'ON', the MINUS input voltage needs to drop slightly below the PLUS input voltage before it turns 'OFF' again (moving left along the top of the loop).

The width of the loop outlined by an off-on-off cycle is the input hysteresis voltage.

The hysteresis voltage for most comparators is in the millivolt range and usually only affects circuits where the input voltage rises or falls very slowly or has voltage spikes known as "noise".

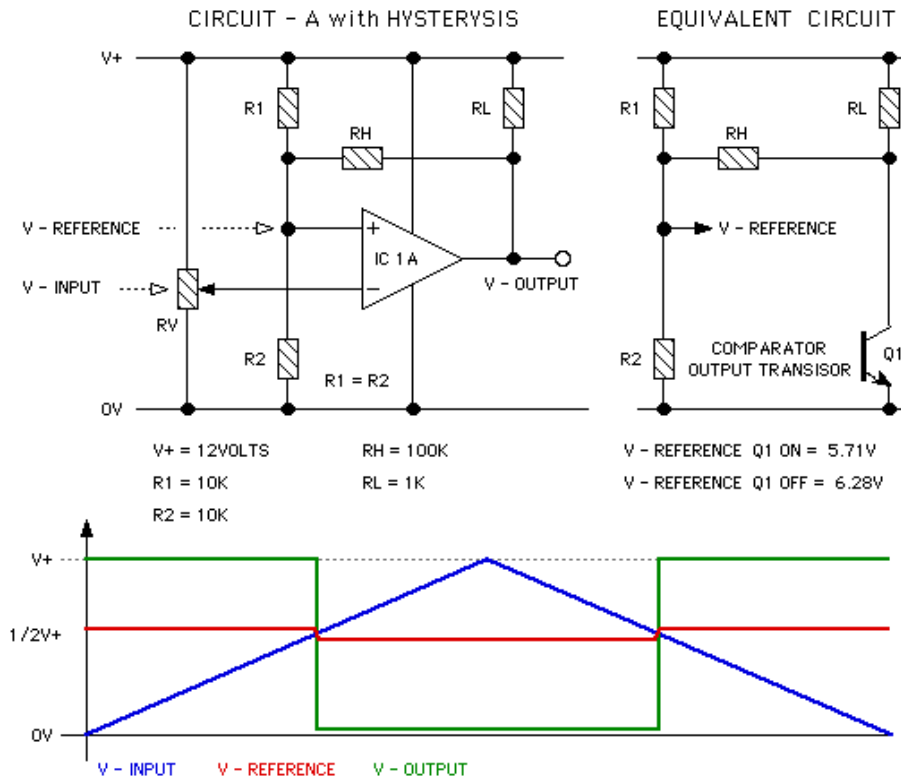
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The Hysteresis voltage range can be increased if needed to help when the input voltage is noisy so the the output does not change states unnecessarily. The FLIP-FLOP circuits shown later on this page make use of an exaggerated hysteresis to create the memory effect.

### ADDING HYSTERESIS TO COMPARATORS

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Comparator Hysteresis b



#### FINDING COMBINED RESISTANCES

OUTPUT TRANSISTOR - ON

$$\frac{1}{\frac{1}{R1} + \frac{1}{RL + RH}} = R1_{combined}$$

OUTPUT TRANSISTOR - OFF

$$\frac{1}{\frac{1}{R2} + \frac{1}{RH}} = R2_{combined}$$

#### CALCULATING REFERENCE VOLTAGES

OUTPUT TRANSISTOR - ON

$$\frac{V+}{R1_{combined} + R2} \times R2 = V - REFERENCE$$

OUTPUT TRANSISTOR - OFF

$$\frac{V+}{R1 + R2_{combined}} \times R2_{combined} = V - REFERENCE$$

- THE VOLTAGE DROP ACROSS THE COMPARATORS OUTPUT TRANSISTOR HAS BEEN IGNORED IN THE ABOVE CALCULATIONS

<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>

### Increasing The Input Hysteresis Range

## Voltage Window Detector Circuit

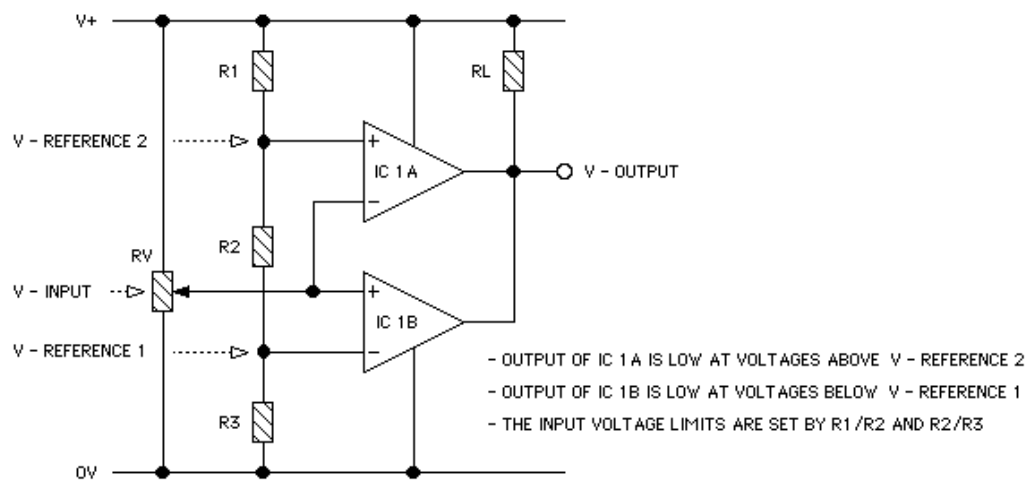
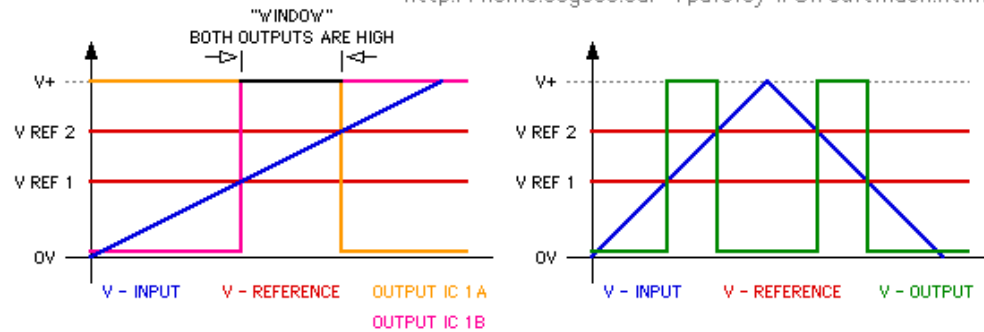
Comparators with Open Collector outputs such as the LM339 or LM393 must be configured so the both outputs are HIGH when the voltage is within the desired limits. The LM311 comparator can have other output arrangements as it has both an open collector and open emitter on the output transistor.



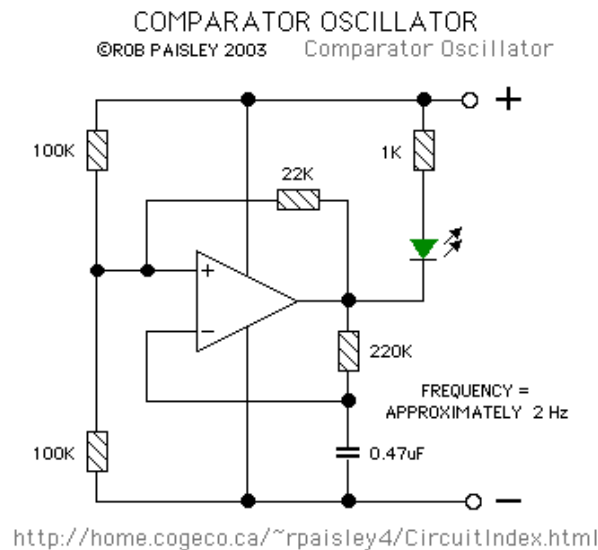
## VOLTAGE WINDOW DETECTOR CIRCUIT

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Comparator Window

<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>**Window Comparator****Comparator Oscillator Circuit**

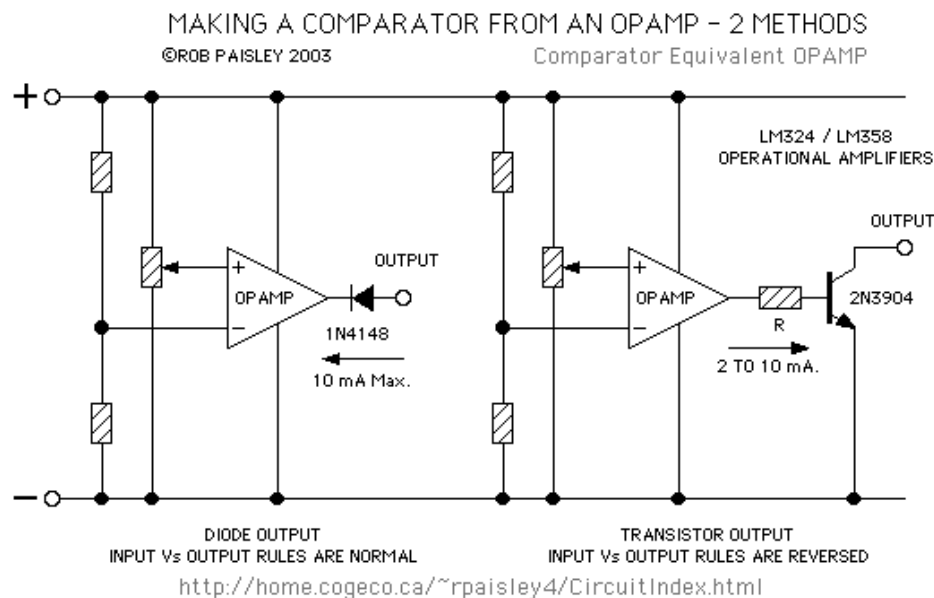
Comparators can also be used as oscillators but are not well suited for this type of application.



### Oscillator Made From A Comparator

## Using An OPAMP As A Comparator

If there are Operational Amplifiers left over in a circuit and a Comparator is needed one can be created by adding a diode or transistor to the amplifiers output depending on the current capacity required.



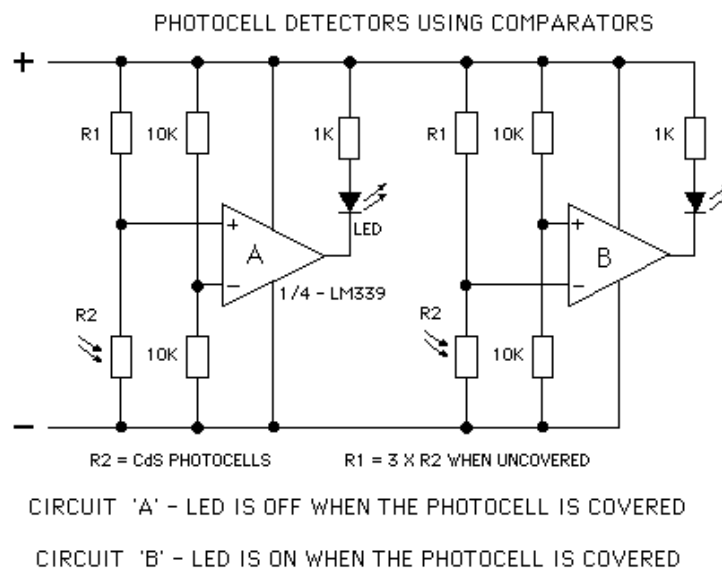
### Comparator Made From An Operational Amplifier

## Basic Comparator Circuits

The following diagrams are of some basic comparator circuits. Most have a Cadmium Sulfide

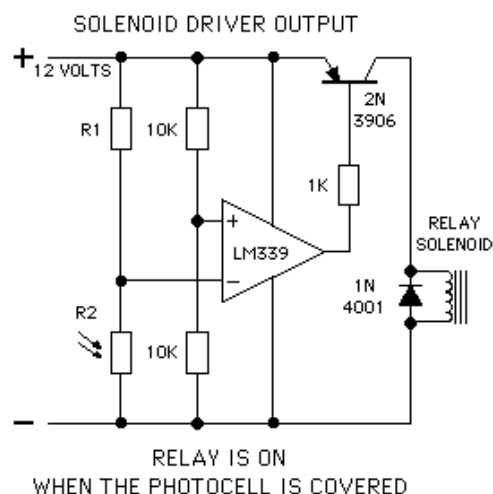
photocell input but could just as easily use a phototransistor or a voltage signal from another circuit as an input. The resistance values are not critical but should be used as a guide. In most comparator circuits the ratio of the resistances is more important than their actual values.

## Photocell Circuits



### Photocell Circuits Schematic

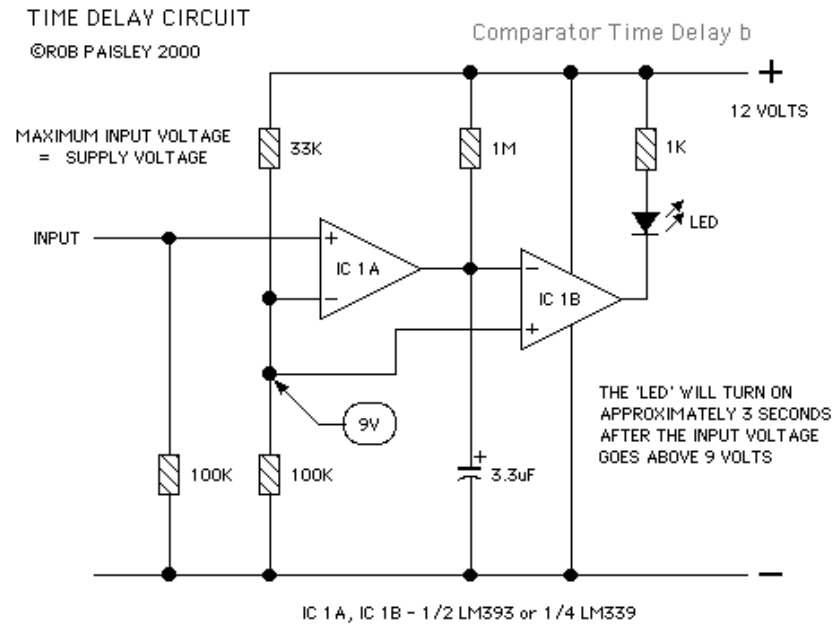
If higher current loads are to be driven a PNP transistor can be added to the comparators output this will allow loads of up to 300Ma. to be controlled.



### Relay Driver Output Schematic

## Time Delay Circuits

Short timing functions such as a pulsed outputs or time delays can also be created with one or two comparator sections.



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### Comparator Time Delay Schematic 1

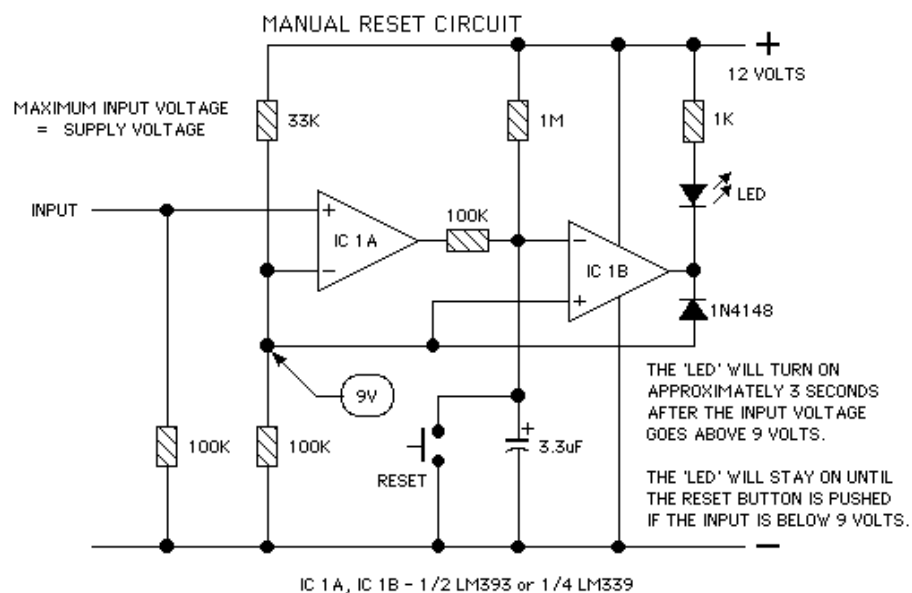
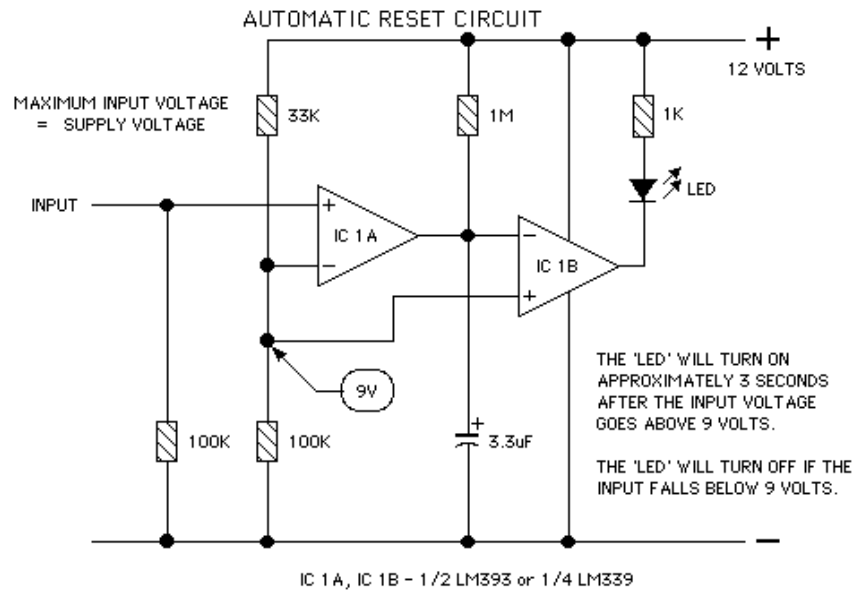
Notice that the second comparator section in the time delay circuit shares the same reference voltage input as the first. In most cases any number of comparators can have the same voltage source at one input, this can make circuits much less complicated.

More Delay circuits.

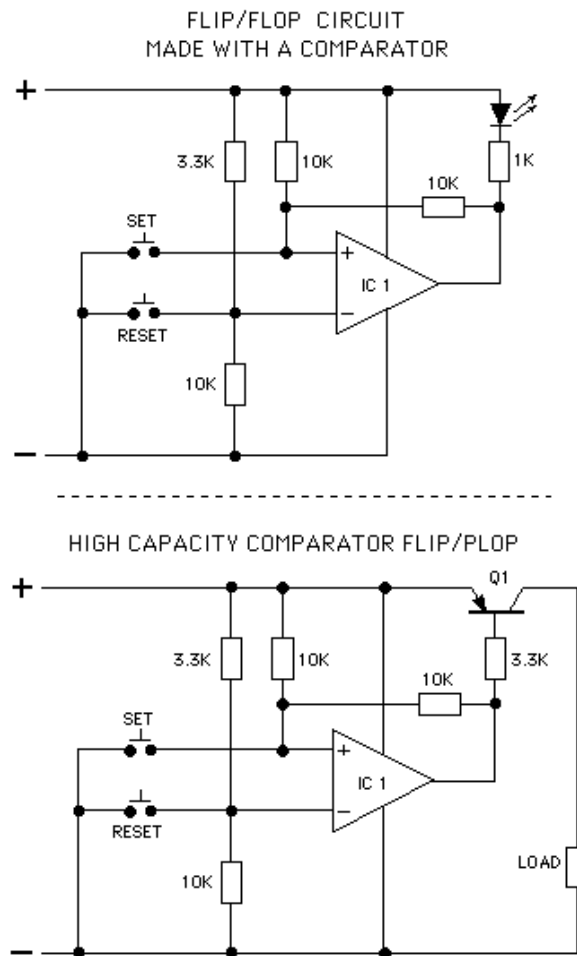
## TIME DELAY CIRCUITS - AUTOMATIC AND MANUAL RESET

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## Comparator Time Delay c

<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>**Comparator Timer Delay Schematic 2****Basic Memory Functions**

Comparators can be made to perform a basic memory function by wiring them as a 'SET / RESET' type of FLIP/FLOP. This type of circuit can be used in unpluggable walk around throttles to remember the direction of the train when the controller is disconnected. In the next diagram the comparator will remember which switch was pushed last. If the 'SET' button is pushed the LED will be on, the 'RESET' button will turn the LED off. A higher current version is also shown.



### Comparator FLIP/FLOP Schematic

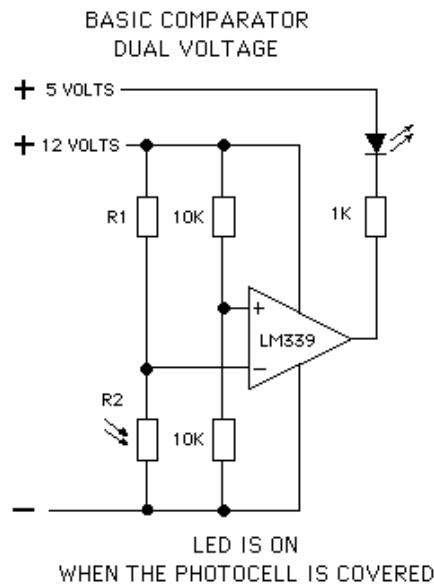
How the Flip Flop works. A very basic description.

1. When the output of the comparator is off the voltage at the PLUS input will be the same as the supply voltage. With the PLUS input voltage higher than the MINUS input voltage the output will remain off.
2. When the SET button is pushed the voltage at the PLUS input will go to zero and the output will turn on.
3. When the SET button is release the voltage at the PLUS input will rise to 1/2 of the supply voltage and the output will remain turned on because the voltage at the PLUS input is remains below the voltage at the MINUS input.
4. When the RESET button is pressed voltage at the MINUS input will go to zero from its normal level of 3/4 of the supply voltage. The output will turn off because the voltage at the MINUS input is below the voltage at the PLUS input. When the output turns off the voltage at the PLUS input will rise to the supply voltage level.
5. When the RESET button is released the voltage at the MINUS input will rise to 3/4 of the supply voltage. The PLUS input voltage will stay above the voltage at the MINUS input and the output will stay turned off.

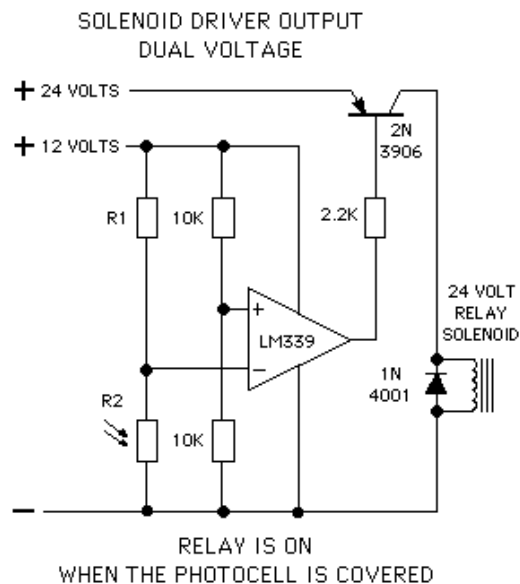
## Open Collector Output Transistors

Because the output transistor of the comparator has an open collector the supply and load voltages do not have to be the same. This means that the comparator could use a 12 Volt power supply while the load could be a 24 Volt relay or 5 Volt LED circuit.

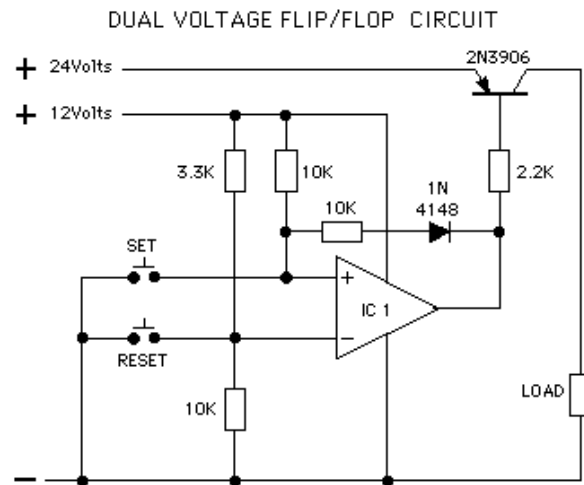
The following three diagrams are some examples of Dual voltage circuits. In the first two the voltage at the output of the comparators could even be full wave direct current.



### Dual Voltage Output Schematic



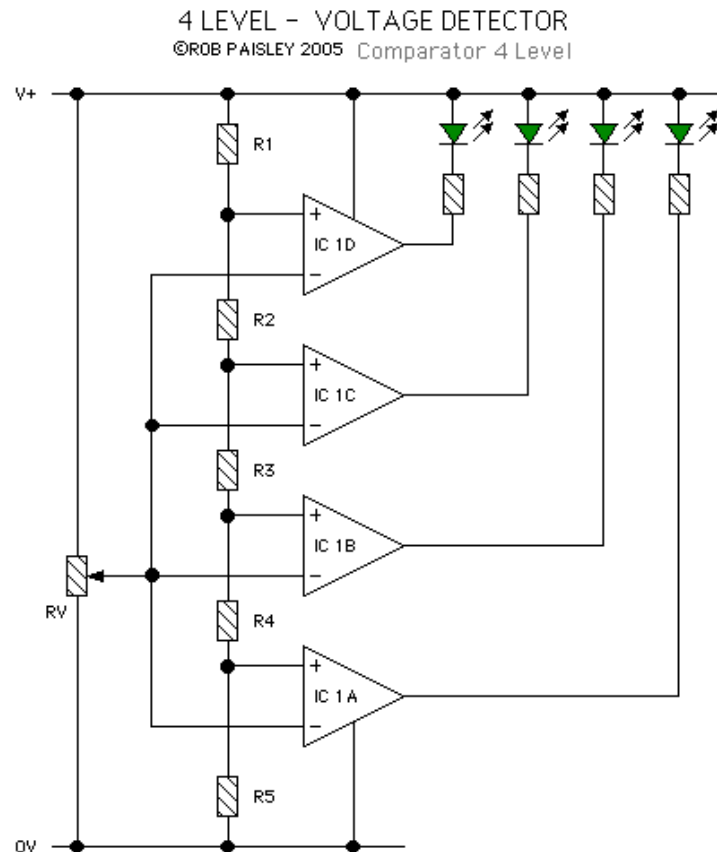
### Dual Voltage Relay Driver Output Schematic



**Dual Voltage FLIP/FLOP Schematic**

## 4 Level - voltage Detector

This circuit can sequentially indicate 4 separate voltage levels. The voltages are determined by the values of resistors R1 through R5 arranged in a simple voltage divider circuit.



R1, 2, 3, 4, 5 - SELECTED TO GIVE THE DESIRED DETECTION VOLTAGE LEVELS  
AS EACH LEVEL IS PASSED THE CORRESPONDING LED TURNS ON

<http://home.cogeco.ca/~rpaisley4/CircuitIndex.html>



## 4 Level Detector Schematic

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